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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Aircraft Engine Operation

Lubrication a Factor in Power Output and Safety

PUBLISHED MONTHLY BY
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Aircraft Engine Operation

Lubrication a Factor in Power Output and Safety

THERE are certain factors involved in the operation of a modern aircraft engine which are entirely unique when compared with the operation of any other type of internal combustion engine, for the aircraft engine is a distinctive type of power plant subjected to operating conditions rarely found elsewhere than in the air.

Upon the proper functioning of this power plant will depend the actual safety and frequently the lives of the occupants of a plane. As a result, such an engine must be faultlessly designed with every attention given to the principles involved. In addition to this, it must be supplied with a grade of fuel capable of dependable ignition and combustion at the proper time with the least possibility of misfiring.

Design and fuel, however, can only be effective provided the engine bearings, cylinders and other mechanisms are kept perfectly lubricated, for it is obvious that any impairment to the lubrication system will cause rapid increase in friction throughout the engine to result in higher bearing temperatures, for example, and a time will ultimately come when bearings will be so damaged or cylinders and piston surfaces so overheated that these parts will seize and the engine will stop.

In view of the fact, therefore, that continued and dependable aircraft engine operation is absolutely contingent upon effective lubrication, it will be well to study the developments which have taken place in this latter over the past few years, and to note the relationship between engine design, fuel combustion and choice of the proper grades of oil to meet the operating conditions.

Requirements of Operation

The outstanding requirements of operation which prevail in the average airplane engine will involve:

1. Normal running at full or very nearly wide-open throttle.
2. Considerably higher compression pressures than encountered in automotive practice.
3. The ability to function under a wide variation in atmospheric temperatures and pressures.
4. Means of cooling, capable of adjustment according to the above temperatures and type of engine.
5. Maintenance of lubrication according to the dry sump principle. In other words, two oil pumps are employed; one for circulation of oil to the bearings and cylinders, the other for the purpose of scavenging the crankcase and transmitting oil back to an external cooling tank.

Throttle Control

Under normal conditions of flying, it will be customary to operate an aircraft engine at more nearly full or wide-open throttle than in automotive practice, due to the fact that the aircraft engine will be called upon to run under full load more consistently than any other type of internal combustion engine.

The extent to which the throttle is open will, of course, have an effect upon fuel consumption, and engine durability as well as engine temperature. In the automotive engine, a continued wide-open throttle may be expected to impose such a heavy load as to give rise to overheating and frequently to bearing failure. In the aircraft engine, however, this is precluded by the positive manner in which lubrication is maintained by means of the dry sump system. This is, of course, brought about by the dual pump installation and the removal of the used oil from the engine by the scavenging pump to enable a certain amount of cooling in a storage tank adjacent thereto.

On the other hand, full throttle operation has been found to involve higher fuel consumption than where this opening is reduced to a certain extent. Throttling, however, involves reduction in speed, for it means a reduction in engine revolutions. It is, therefore, a matter to be decided by the individual pilot as to whether speed, or operating economy plus engine durability should be given the most consideration.

Compression Pressures

Another factor which will impose a considerably heavier duty upon the lubricating oil will be the compression pressures during the firing stroke which prevail in the average aircraft engine. As a rule, these will range from 100 to 135 pounds per square inch at average engine speeds; this is considerably higher than found in automotive practice. It is essential to operate the aircraft engine under such pressures, especially for higher altitude flying, in order to insure the required power output, although the use of a super-charger or induction blower is an aid in this regard.

It must be borne in mind, however, that such pressures will result in higher operating temperatures at the cylinder walls and increased pressure upon the lubricating film at the bearings. To offset this, higher lubricating oil viscosities are necessary than in normal automotive engine practice. Especially will this be true in the air-cooled engine wherein the temperatures may be somewhat higher than in the water-cooled type.

Atmospheric Conditions

The fact that the aircraft engine may have to function under widely varying atmospheric temperatures and pressures, depending upon the altitude of flying, will make it necessary to consider the oil viscosity and its ability to form a dependable lubricating film.

Engine Cooling

It is most essential to provide for adequate means of cooling and protection of lubrication while in the air, by either suitable jacketing where a water or chemical cooled vertical or Vee type engine is involved, or by an arrangement of fins on each cylinder as in the air cooled radial engine.

Effective lubrication of cylinder walls especially is directly contingent upon the extent to which they are cooled. Combustion temperatures are comparatively high and it is virtually impossible to prevent transfer of more or less heat to the lubricating film.

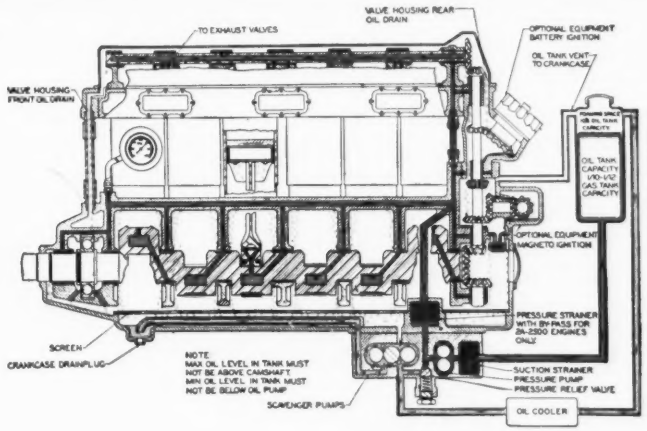
It is practicable, however, to control the rate of heat transfer and the temperature of the cylinder walls, to thereby prevent dangerous reduction in the viscosity of the oil. In the beginning only cylinder walls and piston rings would be affected by the oil being too thin, but due to the fact that the heat transfer occurs within the body of the oil in the system, the bearings would very soon suffer likewise, even to the point of seizure.

As stated, control of engine temperatures is maintained by air or liquid cooling. Where direct air cooling is provided for, as in the radial engine, weight per horse power is reduced and no intricate mechanisms are involved other than suitable fin construction on the cylinders. In the liquid cooled engines, however, the circulating system, pump and radiator must be considered. All involve additional weight. In addition there is the weight of the water or cooling chemical which must be carried. Liquid cooling is, of course, but an indirect form of air cooling, for the liquid after taking up heat from the engine is reduced in temperature by radiation to the air prior to re-circulation.

Liquid cooling, while involving more accessory equipment, may enable operation at somewhat higher engine speeds, although this advantage is claimed to be reduced by the most modern radials. Higher speeds would be advantageous in war time, or where racing planes are involved. Liquid cooling, also, permits of more ready control of engine temperatures under varied air conditions. This is a factor just as in the automotive engine, where complete combustion, fuel economy, power output and maximum engine efficiency are under consideration.

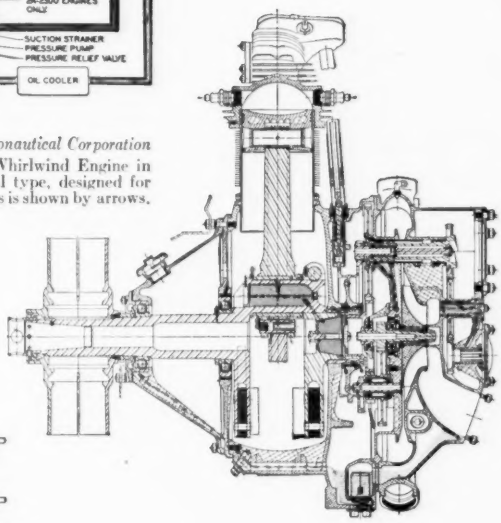
In connection with this matter of liquid cooling, it is well to state that up to the present time water has been chiefly used. There is a considerable amount of research being done, however, in connection with certain chemicals, notably ethylene glycol.

There is an advantage claimed for the latter product, in that it permits of more complete cooling with a considerably reduced amount of coolant. This is, of course, helpful, both from the viewpoint of reduction in weight as well as the degree to which the design of the cooling system can be simplified.


VALVE HOUSING REAR OIL DRAIN
TO EXHAUST VALVES
OPTIONAL EQUIPMENT BATTERY IGNITION
OIL TANK VENT TO CRANKCASE
VALVE HOUSING FRONT OIL DRAIN
OIL TANK CAPACITY 1/10 GAS TANK CAPACITY
OPTIONAL EQUIPMENT MAGNETO IGNITION
PRESSURE STRAINER WITH BY-PASS FOR 2A-2500 ENGINES ONLY
SCREEN
CRANKCASE DRAIN PLUG
NOTE
MAX OIL LEVEL IN TANK MUST NOT BE ABOVE CAMSHAFT
MIN OIL LEVEL IN TANK MUST NOT BE BELOW OIL PUMP
SUCTION STRAINER
PRESSURE PUMP
PRESSURE RELIEF VALVE
SCAVENGER PUMPS
OIL COOLER

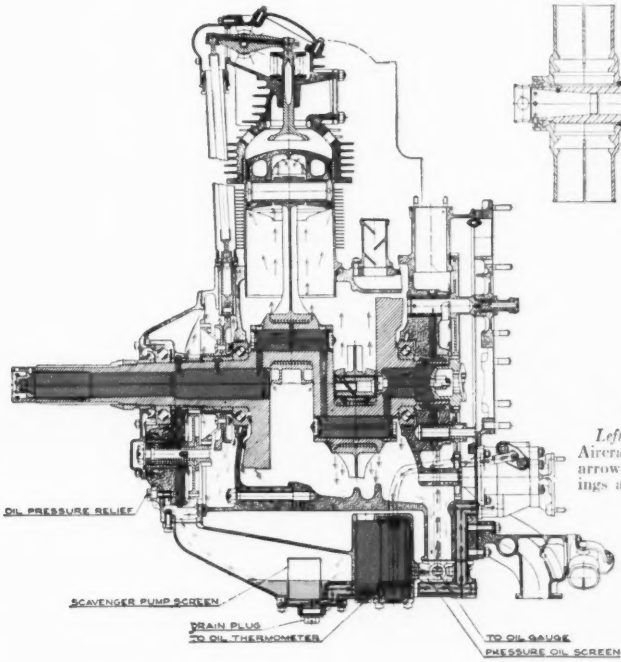
Courtesy of Packard Motor Car Co.

Left—Sectional side view and oiling diagram of the Packard 12 cylinder, "V" type aircraft engine (models 2 A-1500 and 2 A-2500). Red shows oil supply under pressure to engine, green shows return oil and system of scavenging.



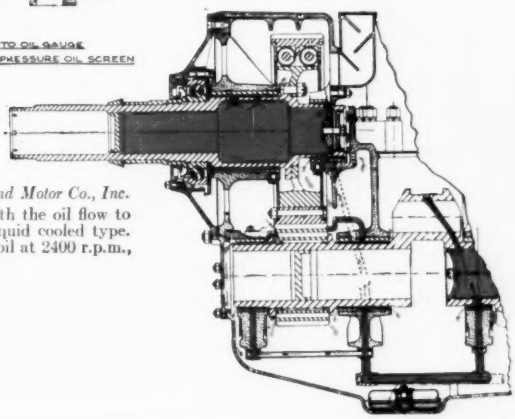
Courtesy of Wright Aeronautical Corporation

Right—Side view of a Wright Whirlwind Engine in detail. This is a 9 cylinder radial type, designed for pressure lubrication. Oil to bearings is shown by arrows.



Courtesy of Curtiss Aeroplane and Motor Co., Inc.

Left—Lubrication chart of the Curtiss Challenger Aircraft Engine. Oil under pressure is shown in red, arrows indicate the course of travel to the engine bearings and other moving parts.

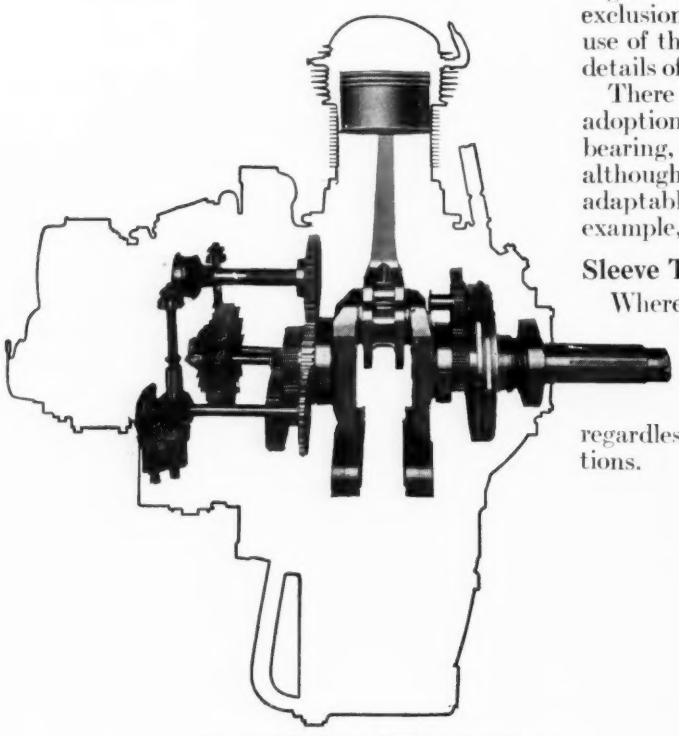


Courtesy of Curtiss Aeroplane and Motor Co., Inc.

Right—Showing part of a Curtiss Conqueror Engine with the oil flow to one cylinder. This is a 12 cylinder "V" engine of the liquid cooled type. It is equipped with a geared oil pump designed to deliver oil at 2400 r.p.m., at 120 lbs. pressure.

Dry Sump Lubrication

Full pressure lubrication is employed in the modern radial and in-line type engine. In contrast with automotive practice such engines usually operate with a dry sump.



Courtesy of The Pratt and Whitney Aircraft Co.

Fig. 5—Showing the internal mechanism of the Pratt and Whitney Wasp Engine, with respect to the engine housing as a whole. This is an extremely valuable illustration for it brings out the relative size and location of all the main operating parts.

Pertinent Advantages

There are distinct advantages pertaining to dry sump lubrication in an aircraft engine; i.e.,

1. It enables more complete cooling of oil in an external cooling tank prior to recirculation. It, therefore, aids in bringing the oil more nearly back to its proper operating viscosity prior to being again subjected to service.
2. It obviates flooding of the cylinders when angle or inverted flight is necessary, such as when banking or taking sharp turns, or looping.

PRINCIPLES OF LUBRICATION

Engine and Bearing Construction

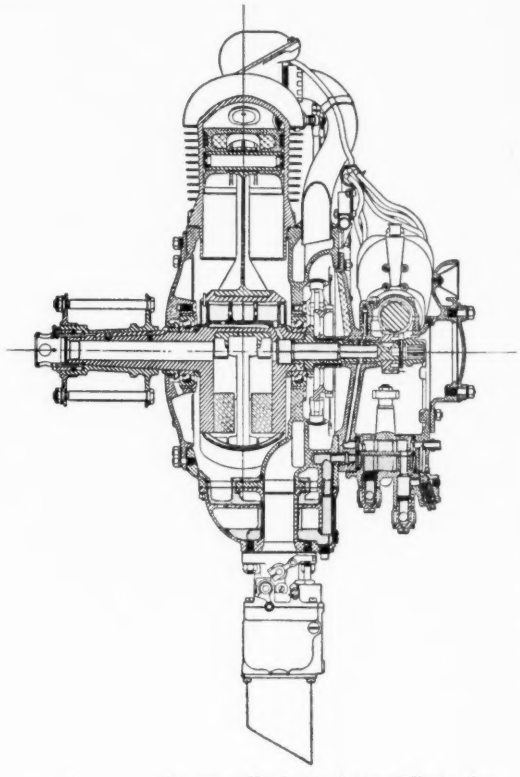
In order to get a better realization of the lubricating requirements of an aircraft engine, it will be well to study the principles of engine and bearing construction.

The aircraft engine will be found to employ bearings of both the sleeve and anti-friction type. In the vertical or Vee engine the plain or sleeve type bearing is extensively used. The principles of lubrication of such engines, with design of the lubricating system, are very similar to those involved in the average automotive engine. The most outstanding difference is the exclusion of oil supply from the crankcase by use of the dry sump system, of which the basic details of operation have already been discussed.

There is marked tendency, however, towards adoption of the anti-friction (ball or roller) bearing, especially in the radial type of engine, although such elements have also been found adaptable to connecting rod bearings, for example, in certain Vee type engines.

Sleeve Type Bearings

Where bearings of this type are involved the essential problem which must be solved in lubricating will be to maintain a continuous oil film within the comparatively small clearance spaces, regardless of operating temperature fluctuations.



Courtesy of The Le Blond Aircraft Engine Corp.

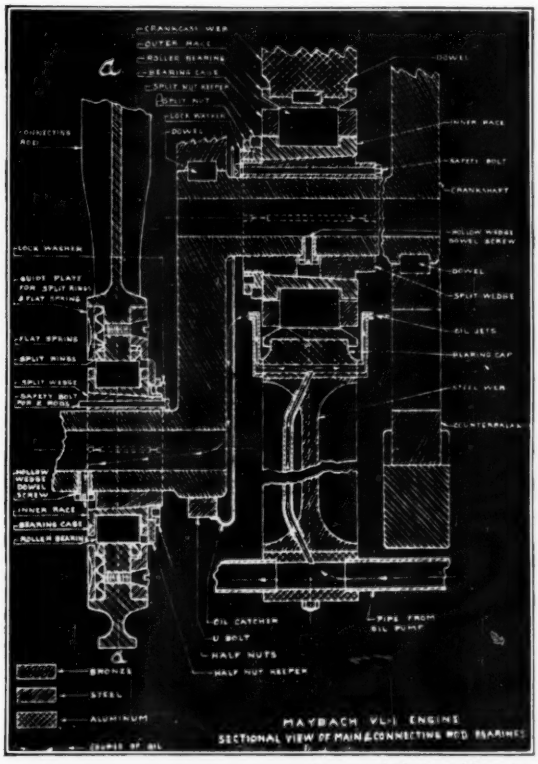
Fig. 6—Showing a section of the Le Blond "60" Model 5D Aircraft Engine.

Bearing Clearance

As a general rule the amount of clearance which will be found in the plain bearings of an aircraft engine will frequently be greater than in an automotive engine, although clearances

will, of course, vary according to the size of the shaft or pin and temperatures maintained.

Experience indicates that an allowed clearance of 0.001 inch for each inch of shaft or pin diameter will result in the maintenance of



Courtesy of Maybach Motor Co.

Fig. 7—Cross-section of a Maybach Engine, showing how main and connecting rod bearings can be equipped with roller bearings.

effective lubrication and the development of the least amount of wear, provided, of course, that the lubricating oil is suited to the operating conditions involved.

It is important to remember that such bearings must be as light as possible within the limits of strength required, in order to reduce weight. This is partly the reason why pins and shafts in most cases are of hollow construction.

As a result, lubrication must be absolutely positive at all times to insure complete filling of the clearance space, and elimination of friction as far as possible.

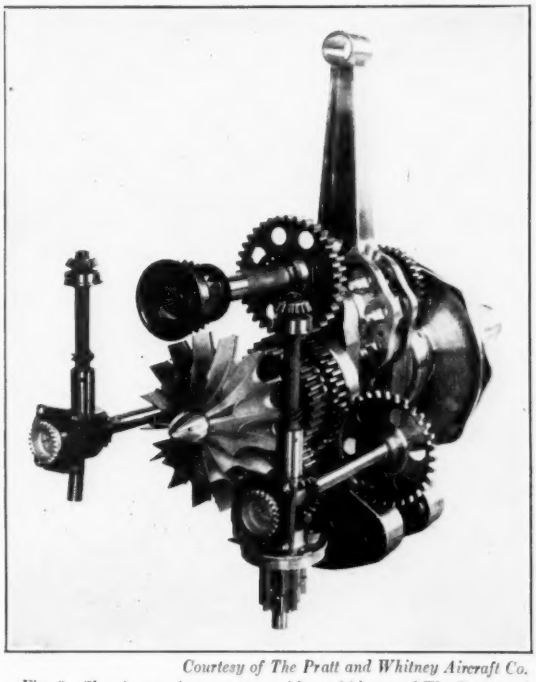
Oil flow, while it serves to lubricate, also affords a most effective means of bearing temperature control. Under the intensive duty involved it is logical to presume that without such a means of partial removal of heat by oil circulation, bearing temperatures would quickly rise to such a degree as to preclude safe engine operation. Such heat as is taken up by the engine oil in circulation is subsequently removed in turn by the oil cooler or tank through which return oil is passed prior to re-circulation.

Oil Grooves Frequently Eliminated

Plain bearings as found in aircraft engine service today will differ from those in certain other types of machinery in regard to their manner of oil grooving. As a rule, there will be fewer grooves cut, or frequently none at all. In part, the reason for this is to avoid decreasing bearing area to any marked degree, and to enable maintenance of higher oil pump pressures. Removal of bearing metal to form a path for oil to follow may also interfere with the formation of the lubricating film; the effective bearing area is also reduced.

It must be understood, however, that where bearings are pressure lubricated, as in the aircraft engine, there will not be the same need for oil grooves, for distribution will be maintained by the oil pressure at the points of delivery.

This pressure can, of course, be varied according to the probable working pressures to be encountered. Automatically it will vary with bearing temperatures. For example, it



Courtesy of The Pratt and Whitney Aircraft Co.

Fig. 8—Showing engine gear assembly and blower of The Pratt and Whitney Wasp Engine. It is interesting to note that certain of these gears are equipped with ball bearings, as is also the blower element.

will be comparatively high when cold starting. As the engine bearings warm up, however, the viscosity or body of the oil will be reduced, facilitating more ready flow through the clearance spaces.

Anti-Friction Bearings

The essential advantages pertaining to the ball or roller bearing in aircraft engine service will involve:

1. Less lubrication,
2. Reduction in overall length of the engine,
3. Lower resultant frictional heat.

Oil pressure does not become as important a factor in the lubrication of anti-friction bearings as it does in plain bearings. This is largely due to the fact that anti-friction bearings involve chiefly rolling motion. As a result, the bearing elements are not so vitally dependent upon the lubricating film as in a plain bearing where sliding motion is involved.

Furthermore, there will normally not be the same tendency towards frictional heat development. In fact, the higher the load or speed the more advantageous will an anti-friction bearing be, due in part to the decrease in frictional heat development and therefore the greater ease with which engine bearing temperatures can be maintained.

Propeller Thrust Bearings

A most interesting instance of the application of the ball bearing is the propeller thrust bearing on certain types of engines. The purpose of such a bearing is to take up end thrust in the shaft as it is developed by the propeller.

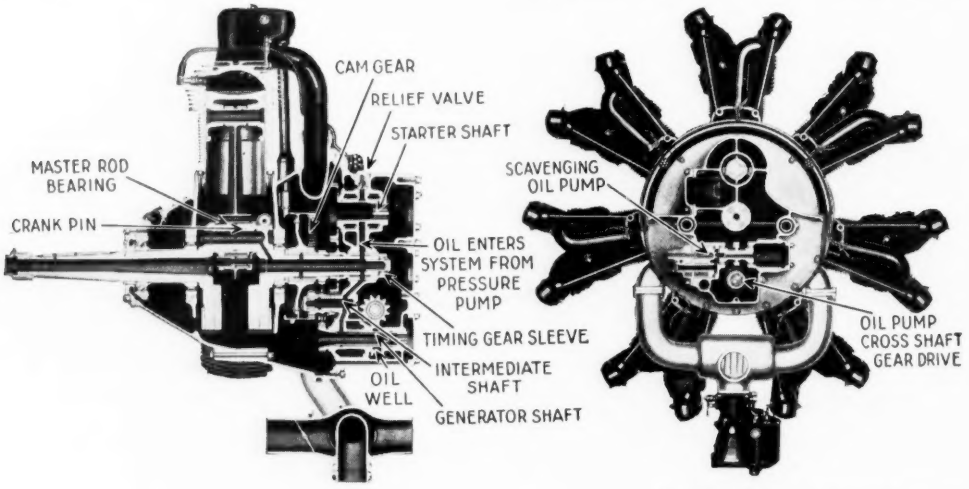
Such bearings, where advantageously located, will usually be lubricated via the main oiling system or by a spray of oil from the overflow from some adjacent bearing.

All such thrust bearings, however, cannot always be so served. Sometimes they will be so located as to require individual lubrication via an oil lead installed for this particular purpose.

PREVAILING TYPES OF ENGINES

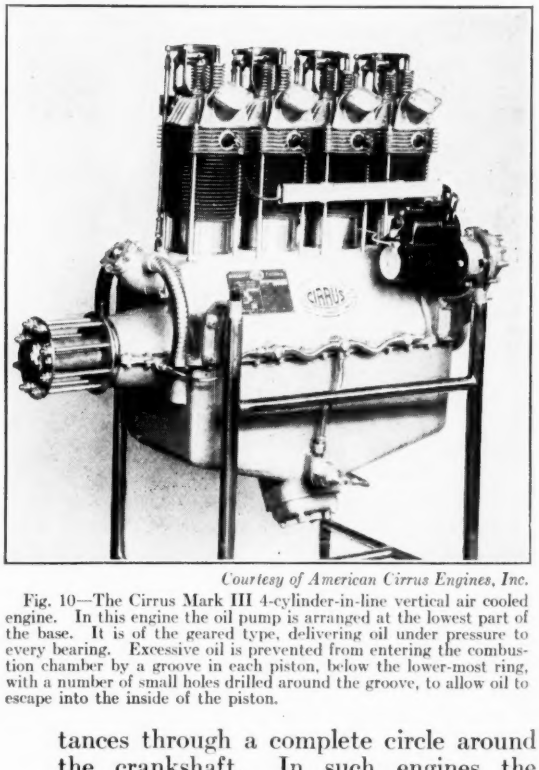
The modern aircraft engine can be grouped into two broad classifications, according to the design and arrangement of the cylinders with respect to the crankshaft. These will include:

1. The Fixed Radial Type, wherein the cylinders are located at equal angular distances through a complete circle around the crankshaft. In such engines the cylinders are stationary, the crankshaft being the revolving element.



Courtesy of Continental Aircraft Engine Co.

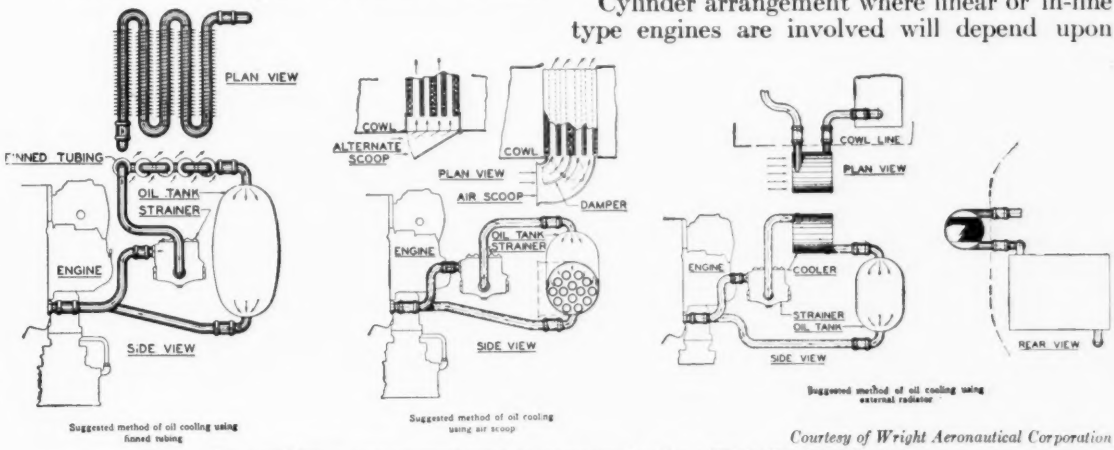
Fig. 9—Side and front views of the Continental Aircraft Engine. The essential parts of the engine, including the oil pump, point of entry of oil, etc., are shown in detail.



Courtesy of American Cirrus Engines, Inc.

Fig. 10—The Cirrus Mark III 4-cylinder-in-line vertical air cooled engine. In this engine the oil pump is arranged at the lowest part of the base. It is of the geared type, delivering oil under pressure to every bearing. Excessive oil is prevented from entering the combustion chamber by a groove in each piston, below the lower-most ring, with a number of small holes drilled around the groove, to allow oil to escape into the inside of the piston.

2. The In-Line or Linear Type, where cylinders are located in line as in an automotive engine. Where but one row of cylinders is involved the engine is termed Vertical. Such engines are chiefly of the valve-in-head type.



Courtesy of Wright Aeronautical Corporation

Fig. 11—Showing three suggested methods for cooling the oil in a Wright Whirlwind Engine.

Where there are two linear rows, it is known as a Vee type. Where three rows of cylinders are involved, it is termed a W type; and where cylinders are opposed, that is, where two Vee type engines are set with one inverted, the arrangement is called an X type. The Vee type engine may also be inverted to enable greater pilot visibility.

The Radial, the Vertical and the Vee type engines are the three outstanding designs in military and commercial service in the United States today.

Radial Engine Details

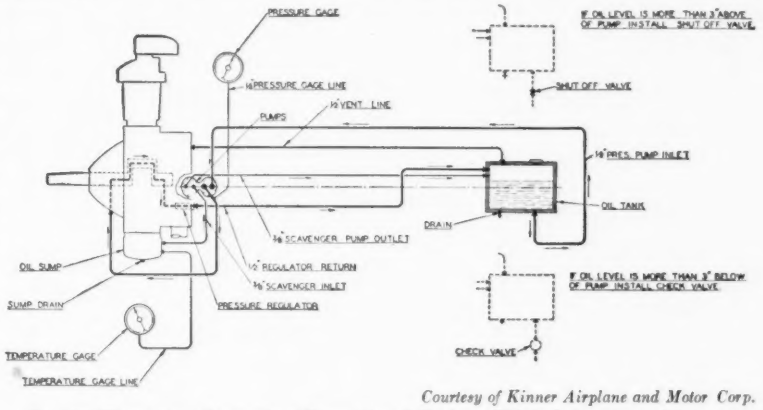
The essential features of such an engine are its low weight per horsepower, the adaptability to air-cooling, the relatively short length, the accessibility of valves and cylinder heads, and the ease with which it can be mounted or detached. A Radial engine offers fairly high wind resistance, however, by reason of its frontal area. This will be especially true of higher horsepower designs.

Three to eleven cylinders will normally be employed in such engines, according to their intended horsepower. Where cylinders are arranged equiangularly, in a single bank and served by the one crank connection, the number must be odd. This is the most usual construction in the modern radial engine. The four-cycle principle is used entirely.

Linear (In-Line) Engine Details

Cylinder arrangement where linear or in-line type engines are involved will depend upon power requirements, frontal area limitations, and fuselage design. Where six cylinders or less are desirable, vertical arrangement is preferred, due to low frontal area and the practicability with which installation can be effected. When power requirements call for eight or more cylinders, however, the Vee type is most commonly adopted.

In such engines a 45, 60 or 90 degree angle will usually prevail, one crank being provided for each pair of cylinders in the same cross-section perpendicular to the crankshaft. The angle of the Vee will, of course, control the ultimate frontal area. As a result, it will frequently be advantageous to reduce the Vee as much as possible. The 12-cylinder Liberty engine, for example, is built with a 45 degree Vee. There are other twelves, however, with a 60 degree Vee, just as there are eights with a 90 degree Vee. Present-day practice indicates pref-

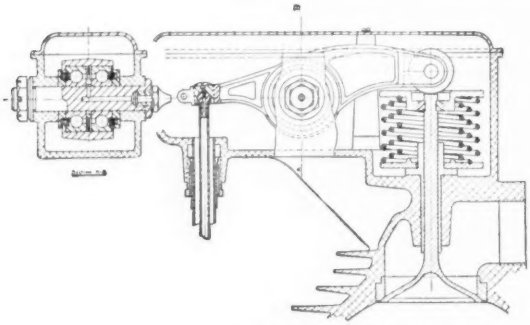


Courtesy of Kinner Airplane and Motor Corp.

Fig. 12—Oiling system diagram for a Kinner Aircraft Engine. This includes a two unit type pump which delivers oil under full pressure to the bearings. The remainder of the mechanism is lubricated by splash thrown from the crank-shaft.

erence of the two former angles due to the smoother operating conditions.

Engines of the W and X type are less commonly used in modern practice today, although extensive research in regard to the latter for



Courtesy of S. K. F. Industries, Inc.

Fig. 13—The detail of a rocker arm assembly, side and front views. This shows the effective manner in which the rocker arm can be equipped with ball bearings. By installing these latter and maintaining effective lubrication, frequency of valve adjustment is reduced.

high speed purposes is being carried on. In the W type engine there are three rows of cylinders, the center one being vertical, the side rows forming equal angles therewith. A typical W type engine will involve twelve cylinders and four cranks—one for each set of three cylinders. Overall length is, of course, reduced by a W type engine, but frontal area is markedly increased.

This will hold true likewise for the X type engine. In addition such engines will be considerably higher, requiring perhaps special fuselage design and construction. From a front view an X type engine may appear to be akin to the radial engine except that all four cylinders will not be spaced equiangularly. The same angle, however, must prevail between each upper and lower pair.

Up to the present time water-cooling of linear type engines has been the most commonly used, although air-cooling of certain types has been found to be entirely practical.

SYSTEMS OF ENGINE LUBRICATION

It may be broadly stated that there are two distinct systems of lubrication, viz.:

1. Where full pressure lubrication is employed, as in the modern radial or in-line type of engine, or
2. Where lubrication is accomplished according to the all-loss method.

In the Radial Engine

In engines of the radial type the former will prevail, as already mentioned. In other words, oil, while maintained in constant circulation through the engine moving elements, is not accumulated in a crankcase or sump as part thereof. Instead, it is removed by suitable scavenge pumps and led to an outside tank, where it is cooled and recirculated by the oil pressure pump. Such pumps may be of the plunger or gear type; the latter predominate. It is interesting to add that over-cooling of the oil in such an engine can be prevented in cold weather by suitably lagging or covering the oil tank.

Oil, as it passes from the pressure pump, is discharged via a main distributing line to the main bearings, crankpin and connecting rod elements; from there it is carried to the piston pins and cylinder walls by centrifugal force.

Rotary Engine Lubrication

Although the rotary engine is relatively obsolete, a word as to its lubrication will be of interest. In engines of this type lubrication may be said to generally function according to the principles of the all-loss system. In other words, there is no re-circulation involved, oil being completely used up in its course through the engine. As a result, such engines will show a comparatively high oil consumption.

One pump will, therefore, only be necessary in such engines; i.e., for initial delivery of the

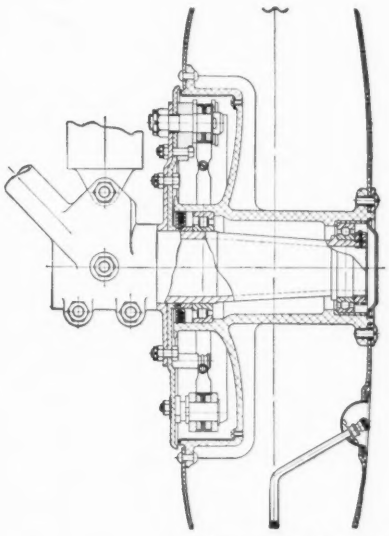
Courtesy of The United States Air Compressor Co.

Fig. 14—Showing lubrication of landing gear elements by means of an electric driven high pressure grease gun.

oil to the main bearings, crank connections and cam gear. From this point lubrication of piston pins and cylinder walls is brought about by the action of centrifugal force on such excess

oil as passes through the pressure lubricated bearings.

Where gasoline is passed through the crankcase prior to delivery to the combustion chambers there will, of course, be contact



Courtesy of S. K. F. Industries, Inc.

Fig. 15—Ball and roller bearings have also been applied to landing gear elements as shown in the above detail of an airplane wheel axle. These bearings, like the rocker arm bearings shown in Fig. 13, are provided for pressure grease lubrication.

between fuel and lubricating oil. This latter must, therefore, be a non-miscible product; that is, it must not tend to become cut back or reduced in viscosity by gasoline. For this reason castor oil is used in such types of rotary engines. Petroleum lubricants cannot serve the purpose, as will be mentioned in a latter part of this article.

Lubrication of the In-Line Type Engine

Pressure lubrication with a dry sump is almost universally preferred in engines of the linear type, just as holds true for the radial engine. The value of the dry sump is that it eliminates the possibility of uncovering of the oil inlet or flooding of cylinders with oil when a plane must dive, climb, bank or loop.

The modern linear type engine is, therefore, equipped with a pressure pump for delivery of oil and a scavenge pump for return of used oil to an oil cooler and storage tank located outside of the engine. The practicability of installing an oil cooler for warm weather flying or a heater for low temperature service is a feature of the dry sump system. The outstanding advantage, however, is the assurance of positive lubrication, regardless of the position of the engine during flight.

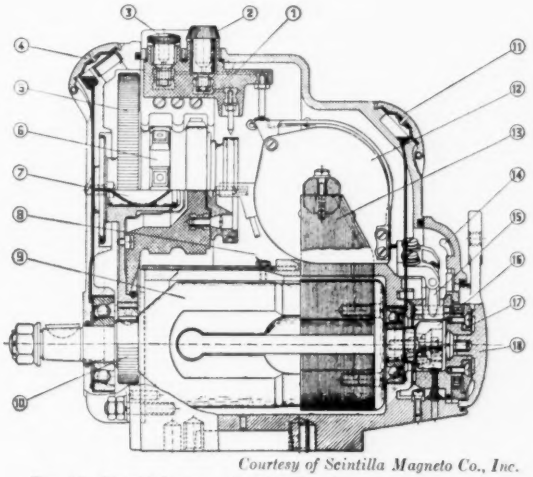
As in the radial engine, the gear type oil pump is preferred for handling of lubricant to and from the working elements of the linear engine. The general course followed by the oil is from the storage tank to the pressure pump in the crankcase, thence through a main distributing line to serve the main bearings. Via suitable holes drilled in the crank shaft, oil is then delivered under virtually the same pressure to the crank pin bearings through the drilled or hollow part of the crank pins.

REQUIREMENTS WHICH THE OIL MUST MEET

In view of the fact that the aircraft engine may involve comparatively low clearances within certain types of sleeve or plain bearings, and extraordinarily high speeds in certain supercharger elements, it will be advisable to discuss the distinctive characteristics which oils for such service should possess.

In brief, these will involve:

1. An ability to withstand abnormal change in viscosity or fluidity under prevailing operating or starting conditions,
2. Low carbon residue content,
3. A minimum tendency to develop gummy residues which might clog the lubricating system and retard free circulation of the oil, and



Courtesy of Scintilla Magneto Co., Inc.

Fig. 16—Detailed view of a Scintilla Aircraft Magneto. At 4 and 11 are shown the front and rear oil holes. Note the ball bearing mountings which carry the rotating magnet (9). The distributor gear, (5) however, is carried by a plain bearing. The latter is wick oiled. The flow of oil is shown in heavy black out-line.

4. A sufficiently low pour test to preclude any possibility of congealment in the pumping system on starting.

It has been proven that straight mineral oils, or in certain types of engines a mineral-fatty oil

compound, will best meet these requirements. The former are chiefly used in the United States. They may be either straight distilled products or blends made from distillates plus highly refined residuals, such as filtered cylinder stocks. The purpose of blending is to gain added viscosity to meet conditions of operation which may involve abnormally high pressures or temperatures.

The science of petroleum refining has been extensively adapted to the manufacture of such products. A most interesting feature has been the ability to obtain distilled oils from crudes of selected base which will have a viscosity as high as 90 to 100 seconds Saybolt at 210 degrees Fahr. Among the advantages of such products is their normally low carbon residue. This will be a decided factor in the reduction of the possibility of development of residues in the lubricating system or around the piston rings.

On the other hand, research in connection with certain Vee-type engines has indicated that a compounded oil, viz.: a straight mineral product containing a slight percentage of selected fatty oil, may be advantageous by reason of the increased degree of oiliness which is imparted by the fixed oil content. It is, however, reasonable to presume that there might be increased possibility of development of gummy residues, for virtually any fatty oil will have this tendency when worked under fairly high temperatures for any length of time.

In fact, this is one reason why castor oil has been so extensively supplanted by petroleum lubricants in aircraft engines of especially the radial, vertical and Vee types. It is still preferable, however, to use castor oil in rotary type engines where principles of design will call for contact of the lubricant with the fuel. In such cases mineral oils, of course, would be so cut back or reduced in viscosity by gasoline as to seriously reduce their subsequent lubricating ability.

Another reason why castor oil has lost favor in connection with fixed type engines has been lack of dependable supply of the properly refined product in the United States. In certain parts of Europe, however, conditions of supply are such as to still render castor oil a preferred lubricant, according to certain authorities.

U. S. Government Aircraft Oil Specifications

In connection with this matter of aircraft engine oil requirements it will be interesting to note the following specifications as adopted by the U. S. Government, viz.:

Name and Grade	Flash Cleveland Open Cup Min. °F.	Viscosity Saybolt Seconds, 210 deg. Fahr.		Pour Max. °F.	Carbon Residue Max. %
		Min.	Max.		
Liberty Aero Grade 1	400	75	85	15	1.5
Liberty Aero Grade 2	400	90	100	30	2.0
Liberty Aero Grade 3	450	90	100	45	2.5
Liberty Aero Grade 4	450	115	125	45	2.5

Reason for Viscosity Requirements

It will be observed that the viscosities required are higher than in average automotive service. The reason for this is the frequently higher engine temperatures which will prevail, the necessity for service under higher pumping pressures, and the desirability of keeping oil consumption as low as possible in order that the amount of oil carried may be reduced.

The higher the temperature, of course, the greater will be the degree of fluidity of any lubricating oil. Such conditions will be especially apt to develop in warm weather flying when the amount of external cooling will be appreciably lower than in cold weather or at high altitudes.

It is, therefore, essential to observe the utmost care in the selection of the proper grade of airplane engine oil which will have a viscosity in conformation with the probable flying and operating temperatures. Haphazard choice in warm weather, for example, may be the forerunner of an excessive reduction in the fluidity of the oil in service, with oftentimes ineffectual lubrication of certain of the wearing parts of the engine, as well as abnormal increase in the rate of consumption. The ultimate occurrence of scored or burned out bearings, of abnormal wear on cylinder walls and an excess of oil pumping past the piston rings will all

lead to a decrease in power output and probably increased cost in engine maintenance.

AUXILIARY LUBRICATION

While the main wearing elements throughout the airplane engine are automatically oiled by the engine lubricating system, there are certain external parts, such as the bearings of valve rocker arms and those of the magneto, which must be independently lubricated by hand. Usually these should be attended to prior to each flight.

Construction of such bearings is such as to insure continued lubrication over the average period of flight, provided that sufficient oil or grease, according to builders' recommendations, is applied prior thereto.

It is interesting to note that the ball or roller bearing has been extensively adopted by many engine builders for their rocker arms. The ball bearing has also been applied to certain types of magneto bearings.

Valve Rocker Arm Bearings and Rollers

On the modern aircraft engine, bearings are usually provided with some form of pressure lubrication. Where they are to be grease lubricated, each bearing is equipped with a suitable pressure gun fitting. While the anti-friction bearing has been extensively adopted in connection with such elements, experience has proven that the plain or sleeve type of bearing will also prove quite satisfactory and efficient, provided that lubrication is properly and regularly carried out, in order to insure a minimum of wear and possibility of faulty valve operation.

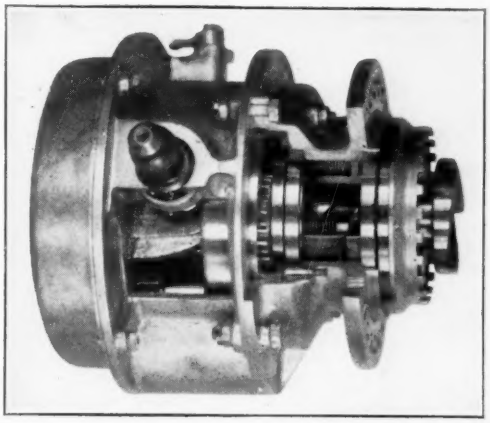
Type of Lubricant

The proper lubricant to use for such bearings will depend upon the design of their housings and the extent to which leakage of oil or grease can be prevented. Where an adequate oil seal is provided, certain authorities prefer a heavy oil of about the viscosity of an extra heavy airplane engine lubricant. The viscosity of such a product would be in the neighborhood of 115 seconds Saybolt at 210 degrees Fahr.

It is so frequently difficult to insure against oil leakage, however, that the practice among engine builders is to provide for grease lubrication of these bearings in their original designs.

To meet the usual conditions of flying, it has been developed that a grease of most careful refinement is necessary. This should be a product of fairly heavy body or consistency, and a high degree of adhesiveness to insure against channeling.

On the other hand, where high altitude flying is involved, or in cold weather, it may be advantageous to resort to a lubricant of lighter consistency which contains an oil of low pour test. Gumming, of course, must be guarded against, otherwise faulty lubrication may occur. This would be apt to develop in low temperature operation, were a heavy oil of comparatively high pour test used, for the amount of heat transmitted to such bearings will be slight. Properly compounded grease, however, will have adequate body to remain within the bearing at normal temperatures, and also possess adequate fluidity by virtue of its oil content to maintain lubrication at low temperatures.



Courtesy of Eclipse Aviation Corp.

Fig. 17—Cut-away view of an Eclipse Aviation Engine Inertia Starter. Operation of this device depends upon the storage of energy in a fly-wheel, which is brought up to a high speed by manual operation of a hand crank. The high speed is attained through the multiple gearing. The energy thus stored up can be expended at the will of the operator in cranking the engine. The starter shown weighs 17½ pounds and is used on engines of 425 H.P. or smaller.

Such lubricants can also be used to wipe the rocker rollers or ball contacts at the same time that rocker arm bearings are lubricated. A light film on these will lubricate sufficiently to effectively prevent abnormal wear.

Magneto Bearings

Lubrication of magneto bearings is of vital importance in connection with operation of the aircraft engine. Ignition must be positive, otherwise serious difficulty may result.

The ball bearing equipped distributor has, therefore, been extensively adopted by aircraft magneto manufacturers, by reason of its elimination of lubrication troubles and the possibility of burning out or seizure of the wearing elements.

Adequate housing of ball bearings will assure positive retention of oil, and relubrication is only essential at infrequent intervals, approximately, every ten to twenty flying hours has been found to be the proper period for oiling during operation, using a highly refined straight mineral lubricant of approximately 200 to 300

seconds Saybolt at 100 degrees Fahr. Zero pour test or better is extremely necessary in such an oil to insure adequate fluidity at low temperature operation.

The amount of oil to use should be determined by the magneto manufacturer. In the Scintilla, for example, 30 to 40 drops of oil should be applied to the front bearing oil holes, with from 3 to 5 drops in the rear bearing oil hole.

Grease lubrication is also necessary on some magneto bearings, provision being made for packing. By virtue of the design and location of such bearings, relubrication is only necessary at the time of engine overhaul, when it is reasonable to presume that magnetos should be similarly overhauled. For such bearings, a high quality grease of medium consistency, capable of standing from 180 to 200 degrees Fahr. should be used.

THE SUPERCHARGER

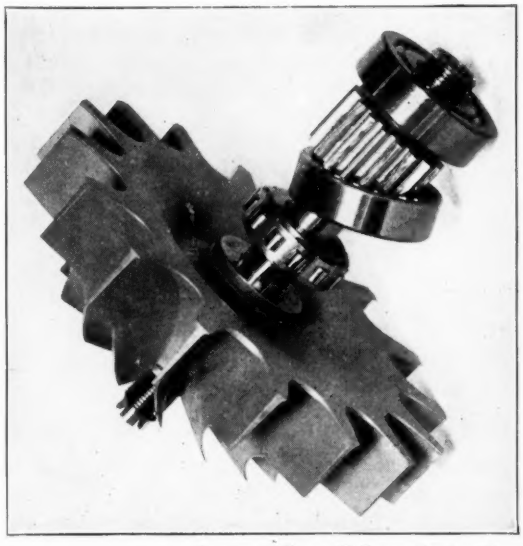
The purpose of the supercharger on an airplane engine is to enable high altitude flying under as nearly as possible sea level atmospheric conditions within the engine. In other words, rarified air as encountered above the earth must be concentrated prior to delivery to the carburetor. Otherwise it will be impossible to maintain the intended gaseous mixture. This would amount to delivery of too rich a mixture, and result in faulty engine operation, crankcase dilution and abnormal carbon formation.

Engine power will depend upon altitude, varying directly as the density of the air involved. At an altitude of 20,000 feet, for example, the brake horsepower will be only about half that developed at sea level.

Suitable compression of air, however, by means of some form of compressor or induction blower, and delivery to the carburetor at a pressure approximating sea level conditions as mentioned above, will result in effective maintenance of engine speed and power.

Supercharging can be accomplished by using either a centrifugal, rotary or reciprocating device. The latter, although adaptable where intermittent delivery of air may be practicable, is virtually obsolete today. The centrifugal and rotary compressor are, however, both highly favored, even though they may sometimes require more careful construction due to the higher pressures involved. With such compressors continuous pressure is involved, being exerted upon the entire volume of air used in combustion.

The operating speed of such a device will depend upon its manner of drive. This, of course, is derived from the engine. It can be brought about by gear drive or by employing the principle of the turbine using exhaust gas as the impelling medium. The latter is capable of developing perhaps the highest speed, although the modern gear drive has been run up to 30,000 r.p.m. where necessary.



Courtesy of Norma-Hoffmann Bearings Corp.

Fig. 18—A high speed super-charger impeller, equipped with roller bearings at the end of the shaft and a closed type ball bearing at the opposite end. This latter not only locates the shaft but also absorbs the impeller thrust.

Installation of a supercharger may be external or internal, according to the type of engine. In a Vee engine the usual practice is to locate this device at the rear of the engine. In the radial engine, however, the supercharger is almost always built into the engine where it acts as a rotary distribution system at part throttle and as a supercharger at full throttle.

Where such construction prevails, lubrication of bearings and driving gears is brought about through suitable leads from the main oiling system, under the same pressure as is directed to the engine bearings. Not only is lubrication thereby positively attained, but also cooling of gears especially is brought about by the flood of oil which is directed to them.

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